SMART|DT

ONNX Example Problem

Disclaimer

ONNX Example

This example is not a real problem. It is meant to be a demonstration of how to use the SMART|DT software.

This problem is inspired by case 5 of ERSI's Stress Intensity Comparisons Round Robin †.

† R. Pilarczyk, J. Guymon, "Engineered Residual Stress Implementation (ERSI) Stress Intensity Comparisons Round Robin", Report Number ERSI-2021-01, Revision IR, 6 June 2022

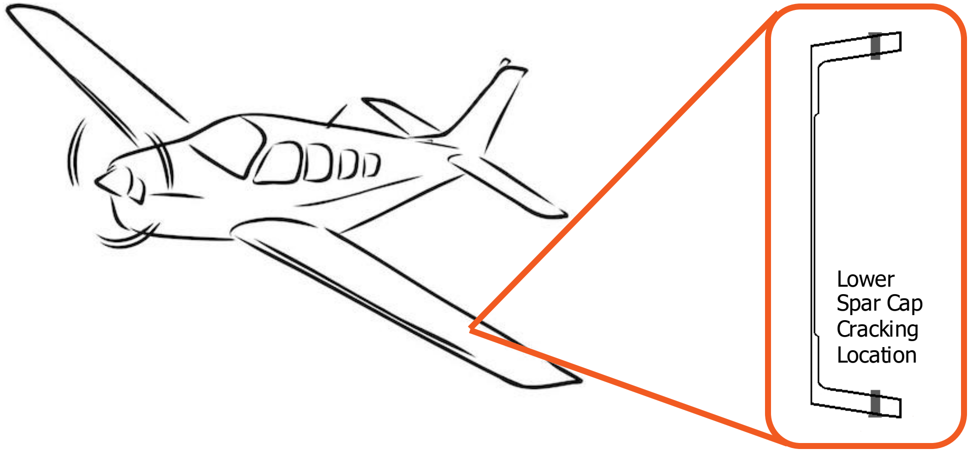
Included in this Example Folder

ONNX Example

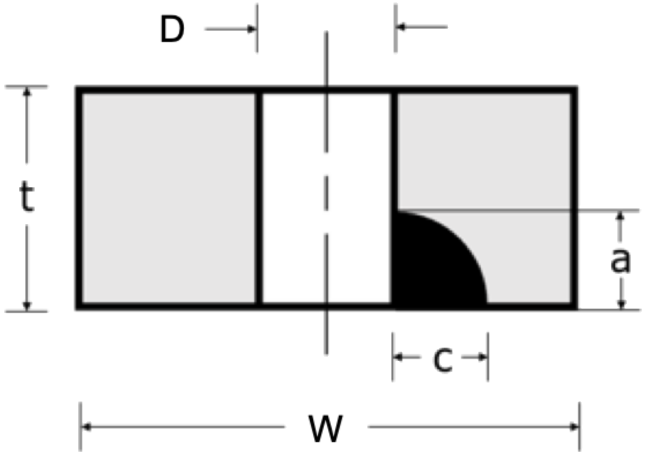
Purpose	File name	Description
Required to develop the example	ONNX_SMARTDT_Example_Guide.pdf	Follow the steps in this file to replicate the example yourself.
	castle-corner_dtdhbk-thru_combined_c5a80_v1.onnx	ONNX file used in the example. Contains the Machine Learning model that computes the K factor.
Reference/comparison of results	ONNX_SMARTDT_Example.smdt	Solved example. Load this file in SMART|DT's GUI to compare your results.
	ONNX_SMARTDT_Example_pof.csv	Extracted from the solved .smdt file. Contains the values of the SFPOF. Can be viewed in Excel or any text editor.
	AR05-15_Kc_calc.xlsx	Spreadsheet containing the equations to compute the Kc value used in the example.

Problem Statement

A single engine turboprop has a corner crack growing in a rivet hole due to fatigue. The hole is located on a lower spar cap. To simplify the analysis, the spar is represented as a flat plate where the crack growth is equivalent to that in the original geometry. Find the SFPOF for the spar using the information that will be provided next.



Parameter	Value
Width [W]	1.20 in
Hole diameter [D]	0.50 in
Thickness [t]	0.25 in



Overview of the Example

ONNX Example

Pane	Feature	Selection
Analysis	Crack growth	HyperGrow
	Crack type	Corner crack in a hole
	Geometry factor	ONNX Model
	Failure definition	Kc
	Probabilistic method	AMIS
	SFPOF Formulation	Lincoln
Material	Material category	Custom probabilistic and deterministic
Geometry	EIFS category	Custom probabilistic
Loading	Type of EVD	User specified EVD

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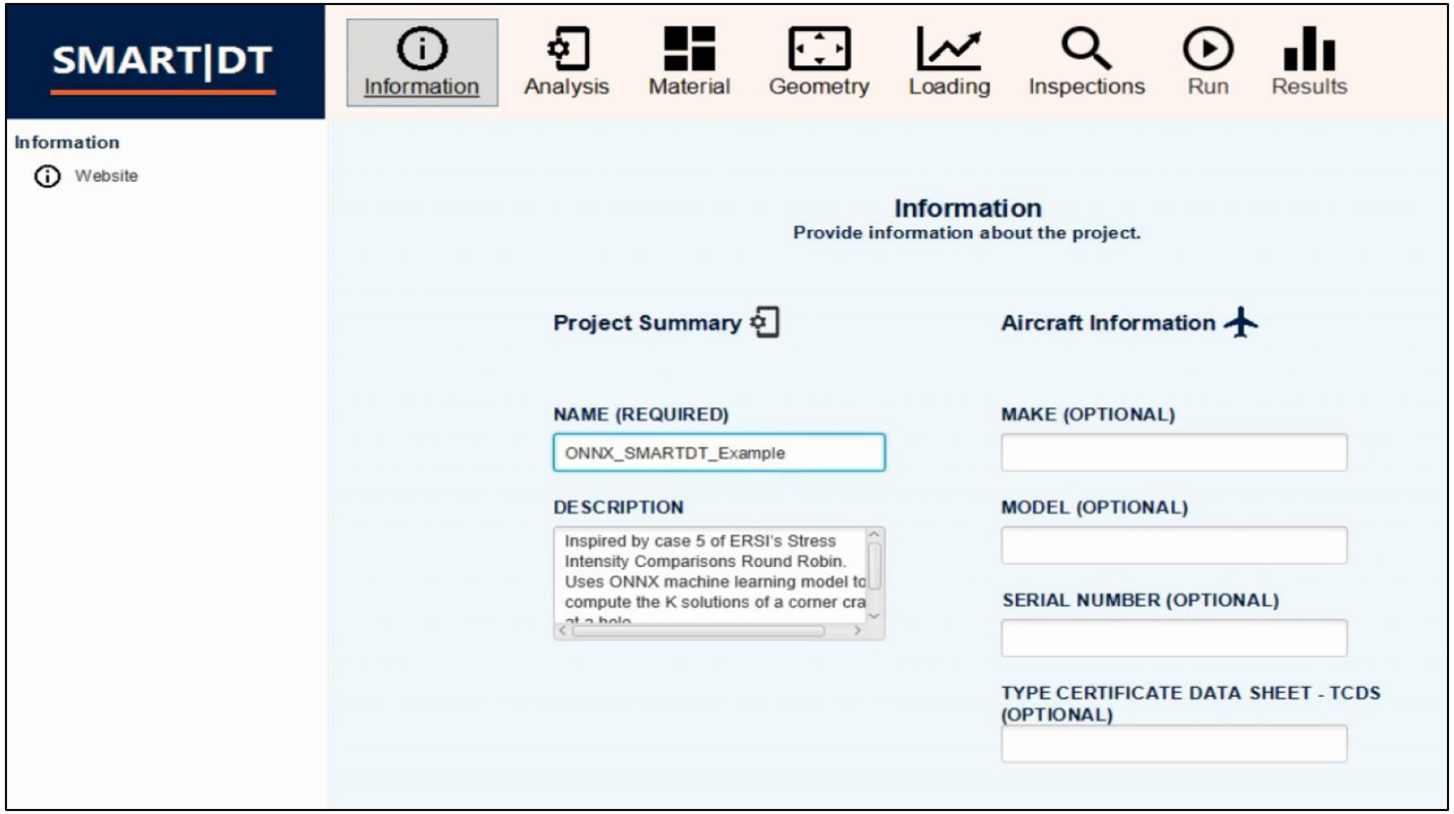
Step 1: Information Pane

ONNX Example



- Open the SMART|DT application.
- Provide a name for the run. We used **ONNX_SMARTDT_Example.**
- The **Description**, **Make**, **Model**, **Serial Number** and **Type Certificate Data Sheet** fields are optional.

Step 2:
Analysis Pane - Output Options

ONNX Example

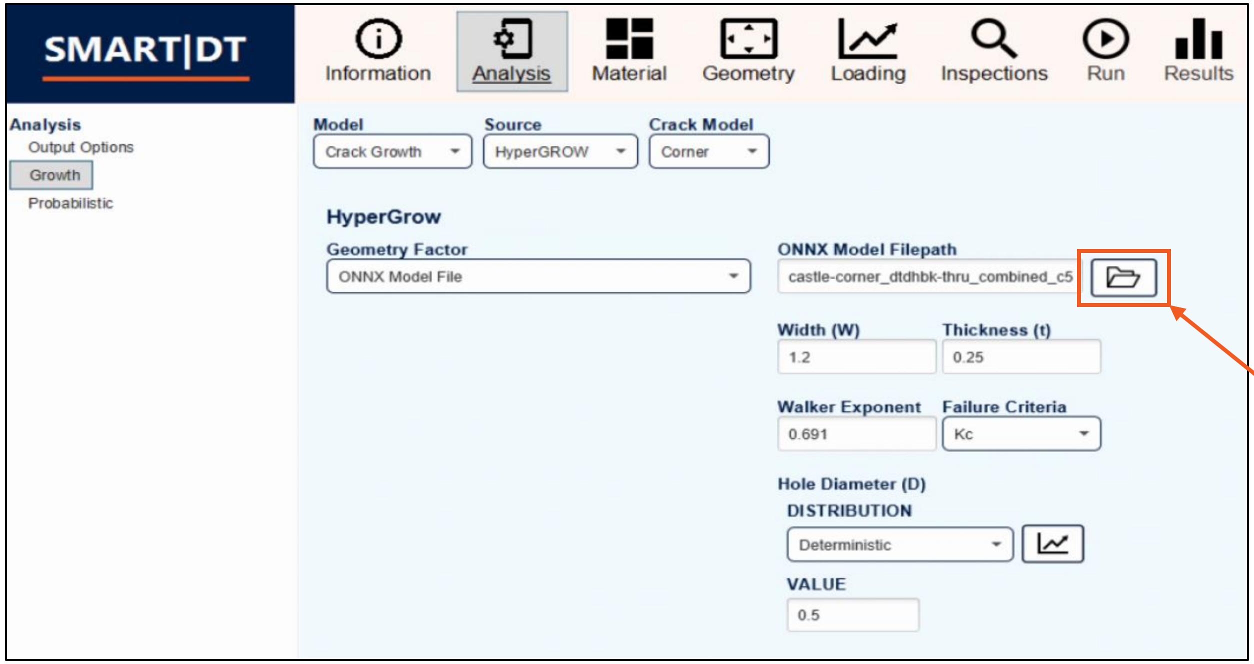
- Select **Flights** and **Lincoln** under the Flight Units and SFPOF Formulation fields.
- Set the Flights and Maximum Flights to the values shown to the left.

NOTES

1) These inputs will generate a SFPOF that was calculated every 100 flights until 15000 flights were reached.

Step 3: Analysis Pane - Growth

ONNX Example



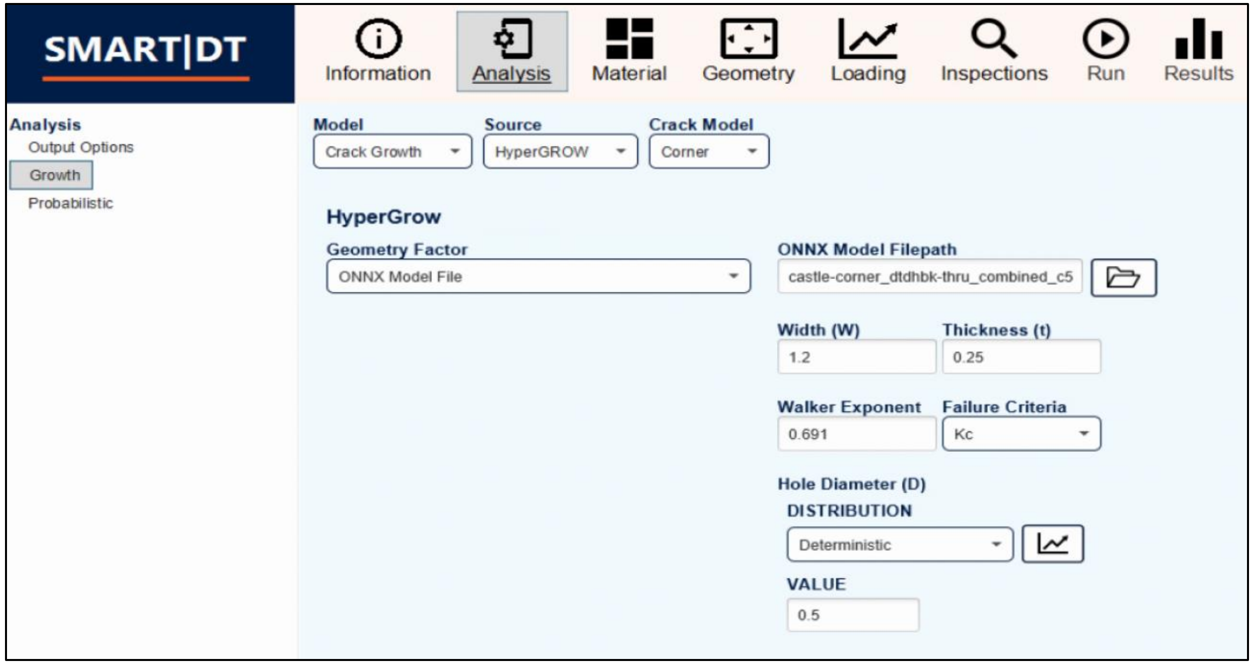
- Select **Crack Growth**, **HyperGrow** and **Corner** under Model, Source and Crack Model fields.
- Select **ONNX Model File** under the Geometry Factor menu.
- Click on the **Browse** icon and select the ONNX model that will be used in the problem. In this case, the file "*castle-corner_dtdhbk-thru_combined_c5a80_v1.onnx*" is used.
- Enter the **Width, Thickness,** and **Walker Exponent**, as shown on the image on the left.
- Select **Kc** under Failure Criteria.
- Select **Deterministic** under Hole Diameter distribution and enter the value shown on the left.

NOTES

1) The ONNX file must be located in the same working directory where the example problem is saved.

Step 3:
Analysis Pane - Growth (cont.)

ONNX Example



NOTES

2) The **HyperGrow** feature performs crack growth in an ultrafast manner without a Master Curve or an external fracture mechanics software. This feature also supports the usage of more random variables in the analysis, such as a probabilistic hole diameter and probabilistic Paris Constants.

3) **ONNX** is a type of file format that can store machine learning models.

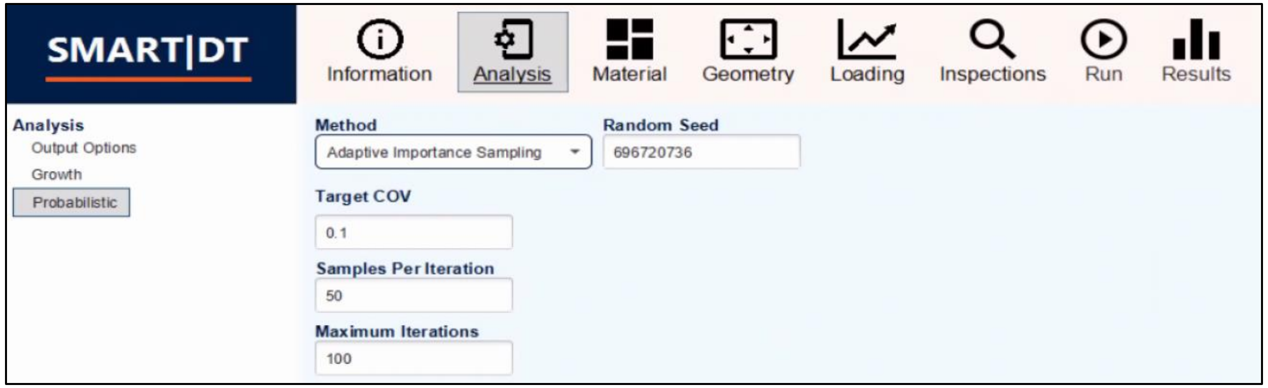
4) The provided **ONNX file** contains a neural network model based on DeepONets, trained on approximately 3 million data points from the CAStLE† FEA dataset for a corner crack at a hole. This machine learning model was developed in collaboration with The University of Utah.

5) Users have the option to **input their own ONNX models** with solutions for different crack geometries.

† CAStLE (USAF Academy) finite element dataset for a corner crack at a hole used for training and testing.

Step 4:
Analysis Pane - Probabilistic

ONNX Example



- Select **AMIS** under the Method field, and enter the Target COV, Samples Per Iteration and Maximum Iterations shown on the left.
- Enter the same Random Seed in your own analysis in order to obtain the same results as the ones reported here.

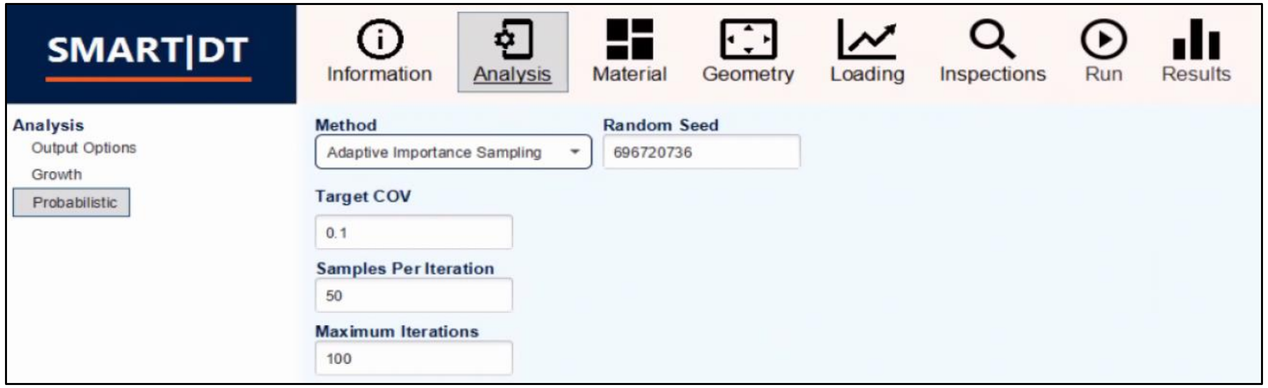
NOTES

1) **AMIS** (Adaptive Multiple Importance Sampling) is an in-house developed method to calculate the SFPOF in a faster and more efficient manner than Monte Carlo. The input values shown here are the default parameters that normally produce accurate results. To learn more about this topic, visit the AMIS training material on the SMART|DT website: https://smartdtsoftware.wixsite.com/smart/copy-of-inspection-fundamentals

2) The **Random Seed** uses the same random numbers every time you pick the same value. This feature is useful for reproducibility of results.

Step 4:
Analysis Pane – Probabilistic (cont.)

ONNX Example



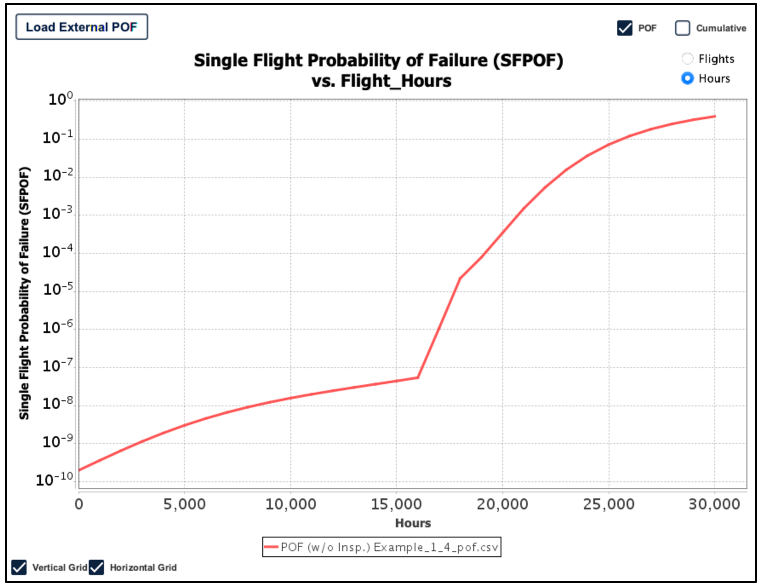
NOTES

3) To estimate the maximum number of samples that could be used in the run, multiply the **Samples Per Iteration x Maximum Iterations**. For this example, 50 x 100 = 5000 samples.

Step 4:
Analysis Pane - Probabilistic (cont.)

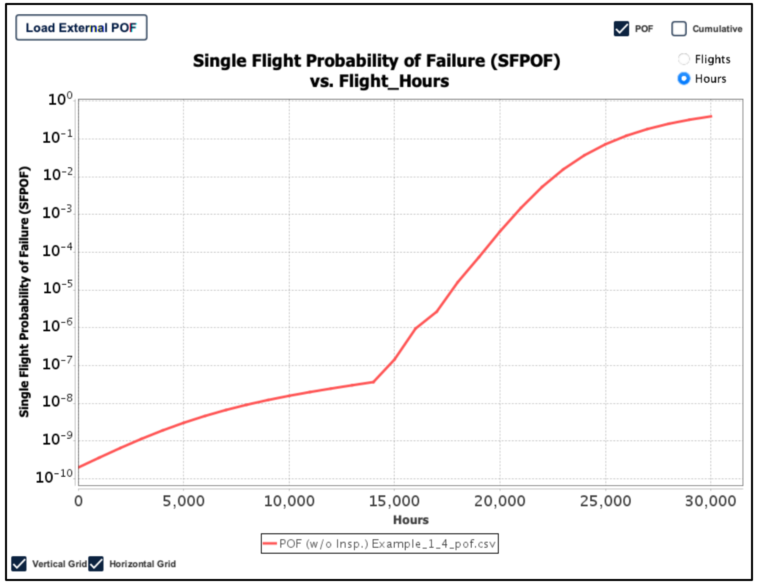
ONNX Example

Monte Carlo 1E6 samples, ~100x runtime



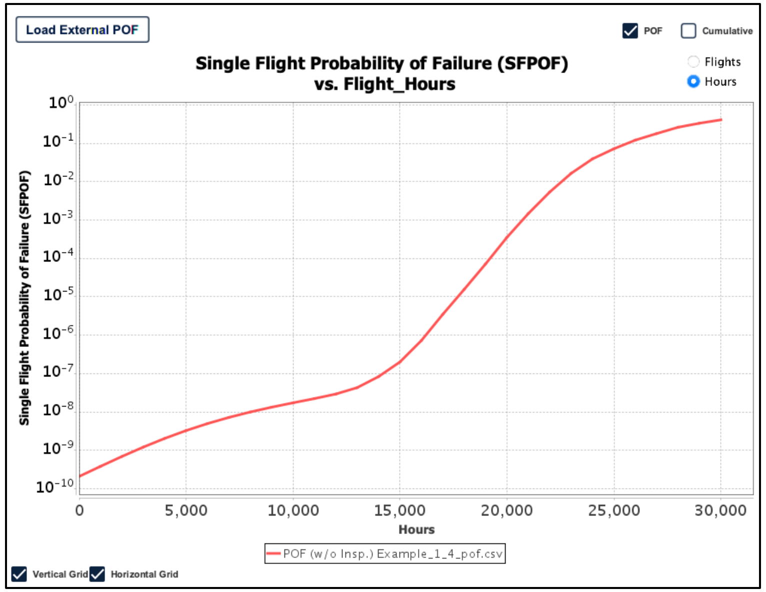

```
Total CPU  time =     68.156 secs
Total wall time =      9.244 secs
```

Monte Carlo 1E7 samples, ~1000x runtime




```
Total CPU  time =    705.253 secs
Total wall time =     95.260 secs
```

AMIS 2300 samples, 1x runtime



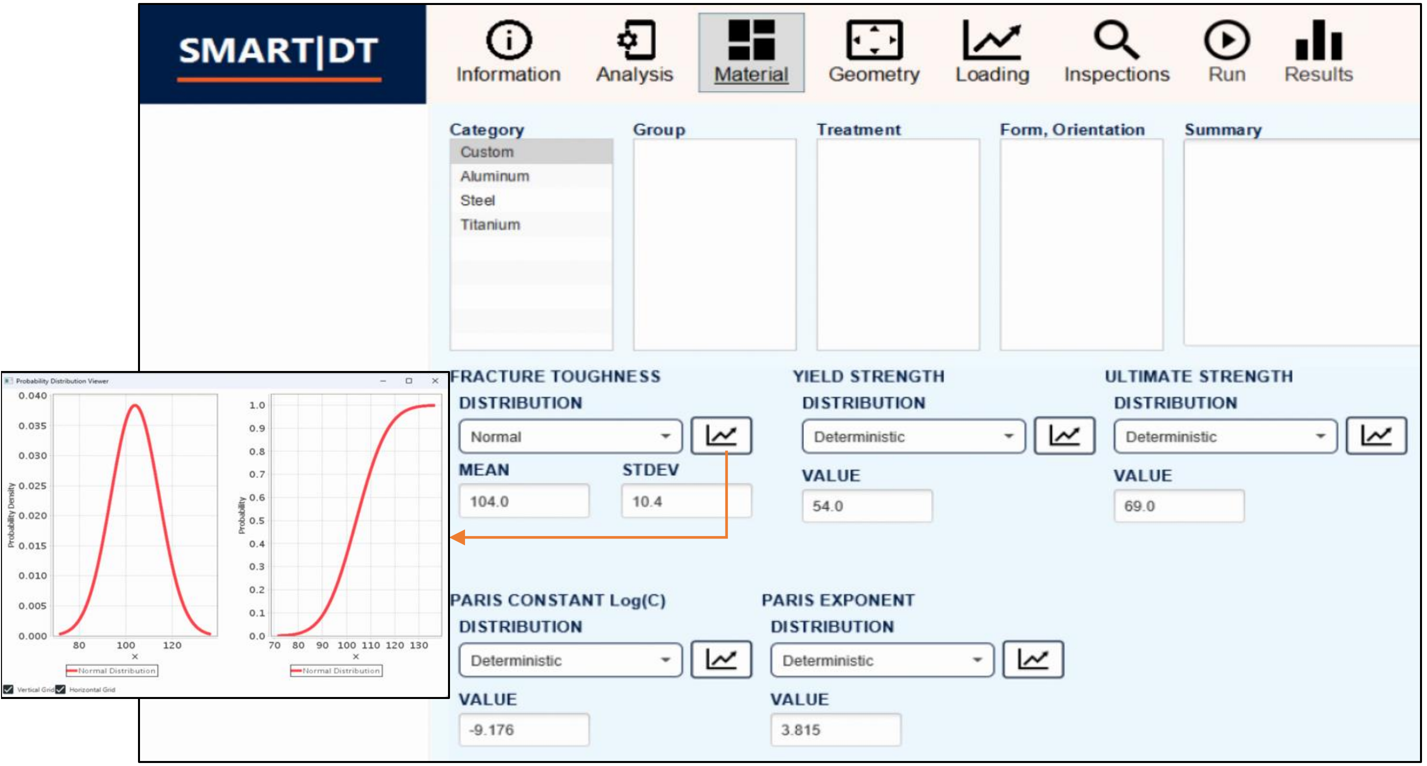

```
Total CPU  time =     0.642 secs
Total wall time =     0.096 secs
```

NOTES

4) In **Monte Carlo**, more samples smooth the SFPOF plot but at the same time they increase the run time. **AMIS** obtains a smooth SFPOF plot with less samples in significantly less time.

Step 5: Material Pane

ONNX Example



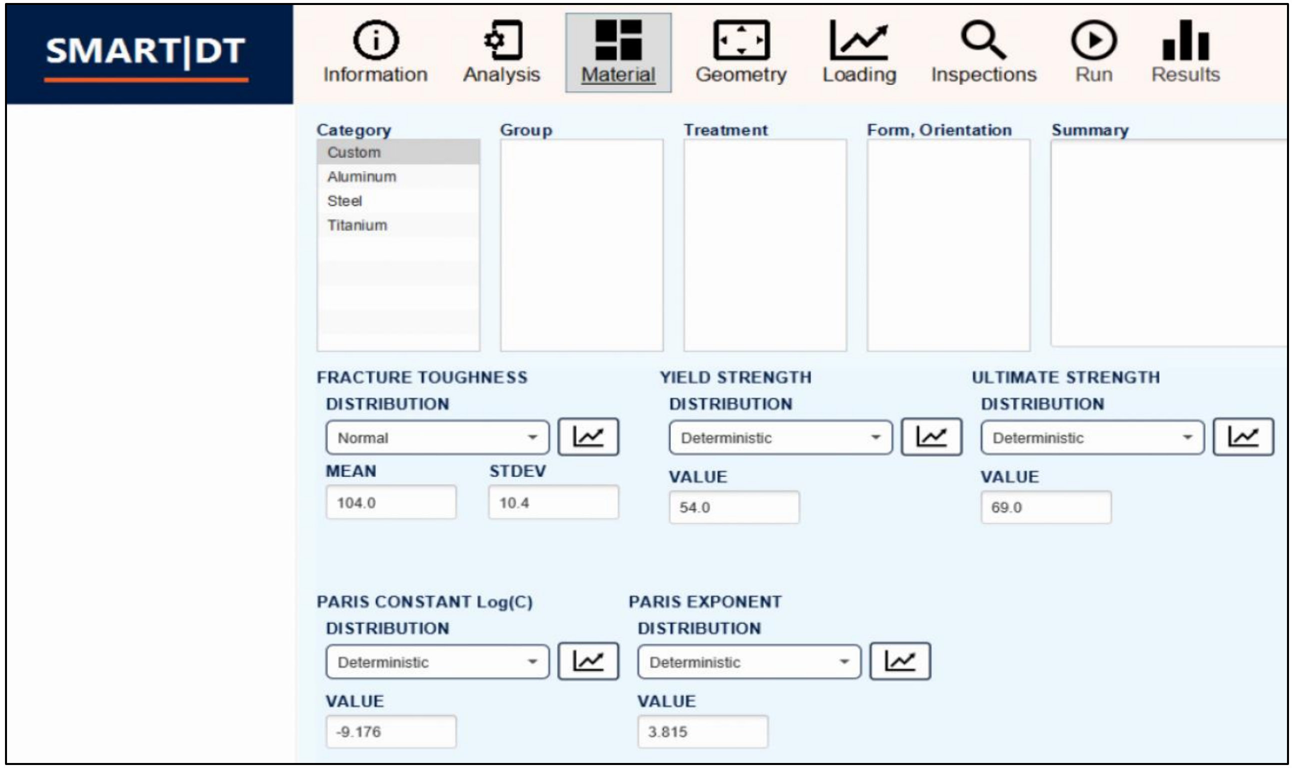
- Select **Custom** under the Category field.
- Select **Normal** for Fracture Toughness, and enter the values shown on the left.
- Select **Deterministic** for Yield Strength and Ultimate Strength, and enter the values shown on the left.
- Use the **Plot** buttons next to the distributions to visualize the parameter variation.

NOTES

1) By using **Probabilistic** data, each sample will use a random material property value from the distributions to calculate the SFPOF.
2) The values used here for Yield and Ultimate strength correspond to those in **Al 2024-T351 Extrusion LT**.
3) The fracture toughness was calculated using the NASGRO equation and AR05-15 (page B-24), as shown in the spreadsheet *“AR05-15_Kc_calc.xlsx”,* included with this example.

Step 5: Material Pane (cont.)

ONNX Example



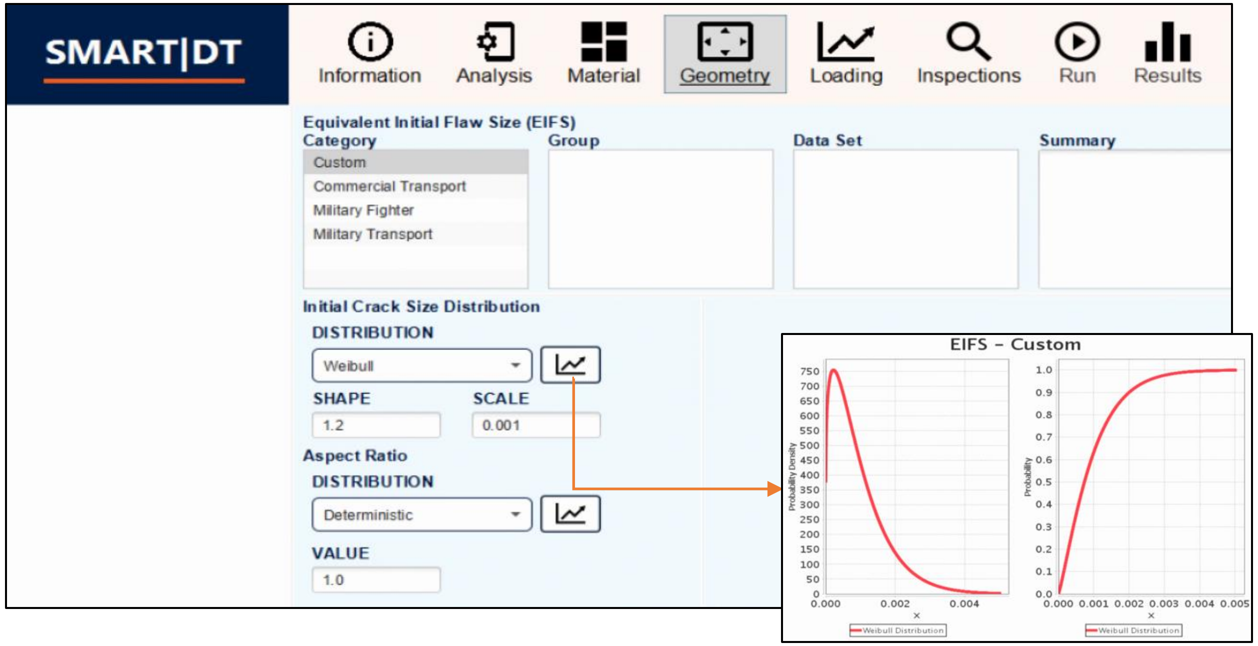
- Select **Deterministic** under the Paris Constant and Paris Exponent fields.
- Enter the values shown on the left.

NOTES

4) Only **HyperGrow** requires the user to enter probabilistic or deterministic values for the Paris constant and exponent. **Master Curve – User Defined** does not require this step.

Step 6: Geometry Pane

ONNX Example



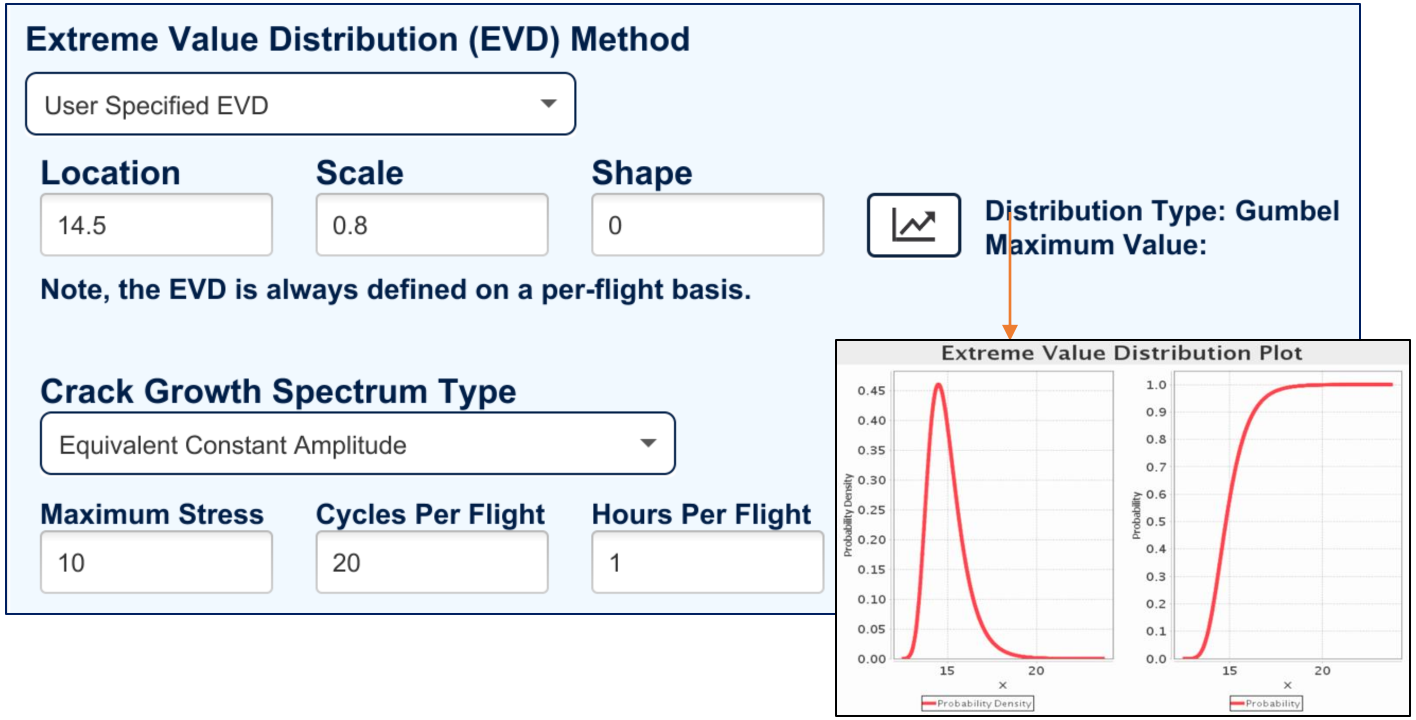
- Select **Custom** under the Category field for EIFS.
- Select **Weibull** for the Initial Crack Size Distribution, and enter the values shown on the left.
- Use the **Plot** button next to the distribution to visualize the parameter variation.

NOTES

1) When **HyperGrow** is used a random initial crack size value from the EIFS distribution is picked to perform the crack growth for each sample.

Step 7: Loading Pane

ONNX Example



- Select **User Specified EVD** under the Extreme Value Distribution (EVD) Method field and enter the values shown on the left.
- Enter the **Equivalent Constant Amplitude Loading** information shown on the left.
- Click the **Plot** button to visualize the EVD.

NOTES

1) The Extreme Value Distribution (EVD) is a probability distribution that defines the maximum stress the component will see in a flight.

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Step 7: Loading Pane (cont.)

ONNX Example

Extreme Value Distribution (EVD) Method

User Specified EVD

Location	Scale	Shape
14.5	0.8	0

Distribution Type: Gumbel
Maximum Value:

Note, the EVD is always defined on a per-flight basis.

Crack Growth Spectrum Type

Equivalent Constant Amplitude

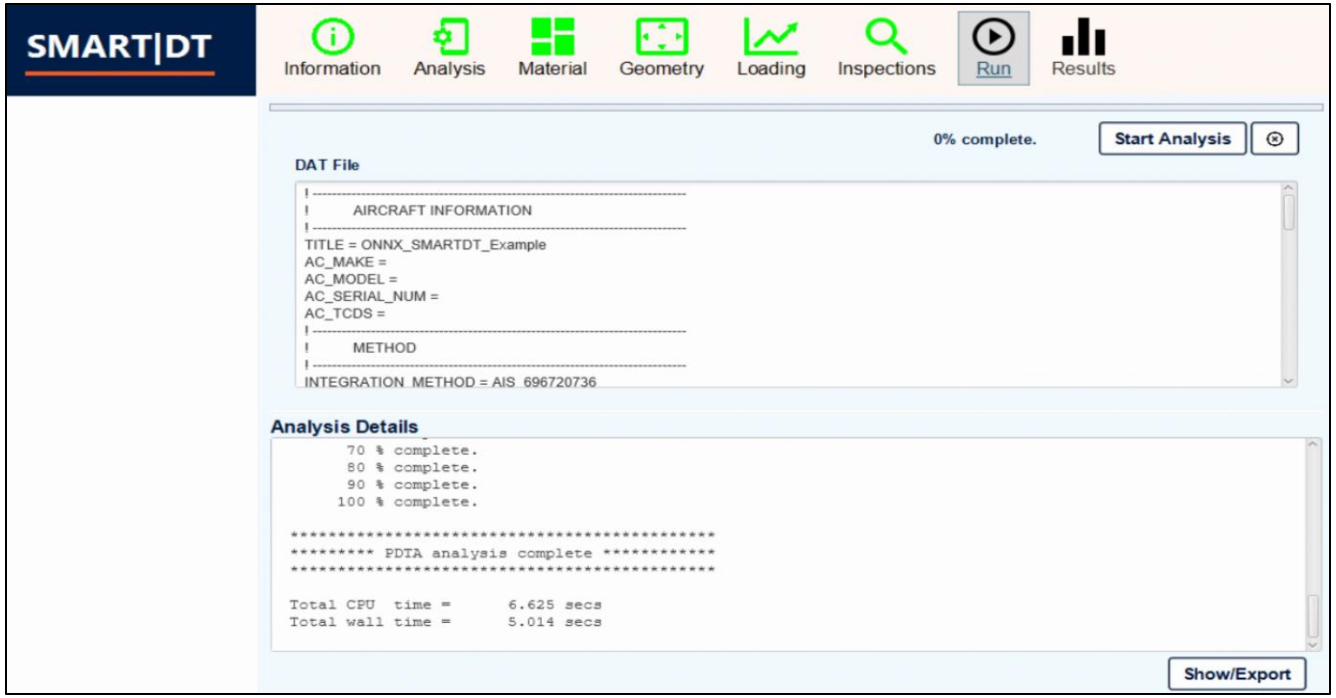
Maximum Stress	Cycles Per Flight	Hours Per Flight
10	20	1

NOTES

2) When **HyperGrow** is used, the user must provide the **Maximum Stress** and **Cycles Per Flight** information in order to perform crack growth. This information is not required for **Master Curve – User Defined**, as the crack growth was previously performed.

Step 9:
Run Pane

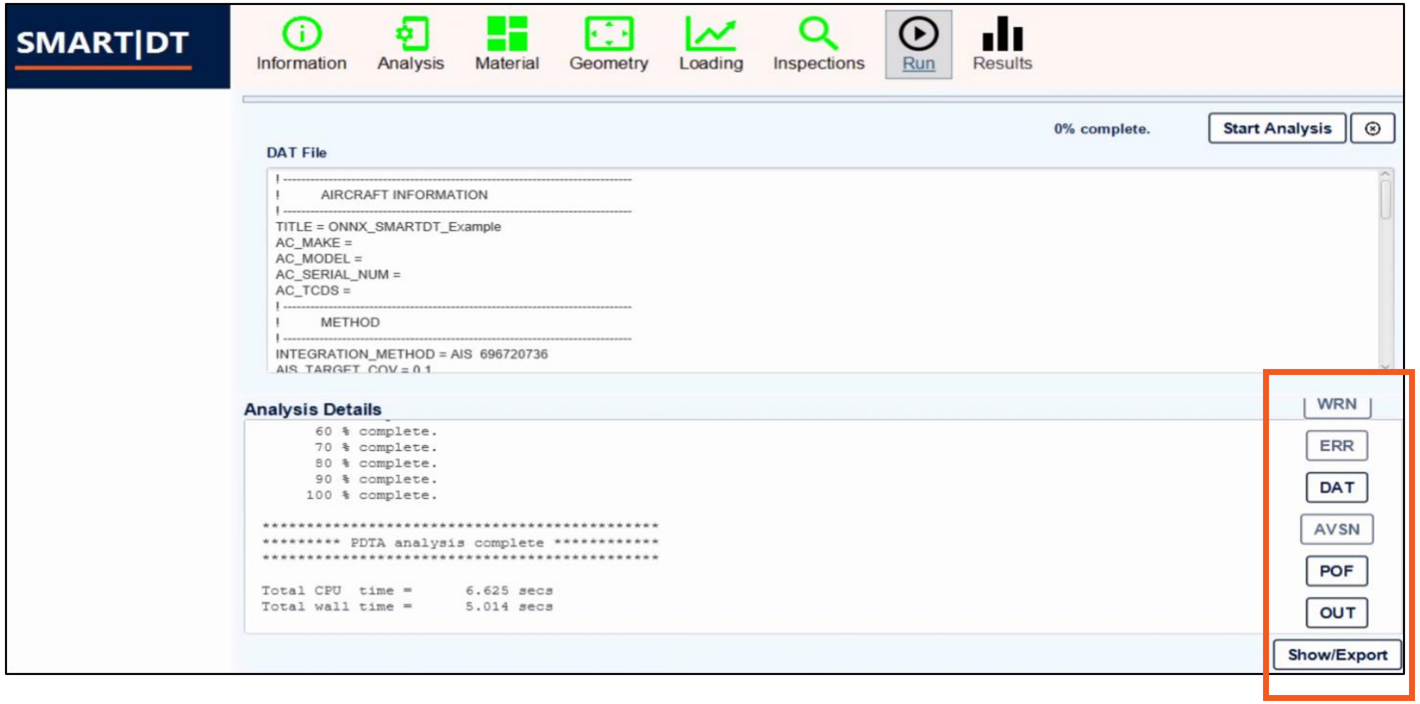
ONNX Example



- Once all panes have been filled out successfully, they will light in green.
- Click the **Start Analysis** button to obtain the SFPOF results.
- The **Analysis Details** window provides a real-time summary of the run.
- Use the **Show/Export** button to obtain more information about the run.
- Click the **X** button on the top right corner of the screen to stop a run.

Step 9:
Run Pane (cont.)

ONNX Example



NOTES

1) **OUT option:** Contains a summary of the inputs and outputs of the run.
2) **POF option:** Contains the SFPOF results. Can be exported as a .csv file for future use.
3) **DAT option:** Contains the inputs of the run.
4) **WRN and ERR options:** Contains warnings or errors found in the run.
5) **AVSN option:** Only available when Master Curve – HyperGrow is selected in the analysis pane.

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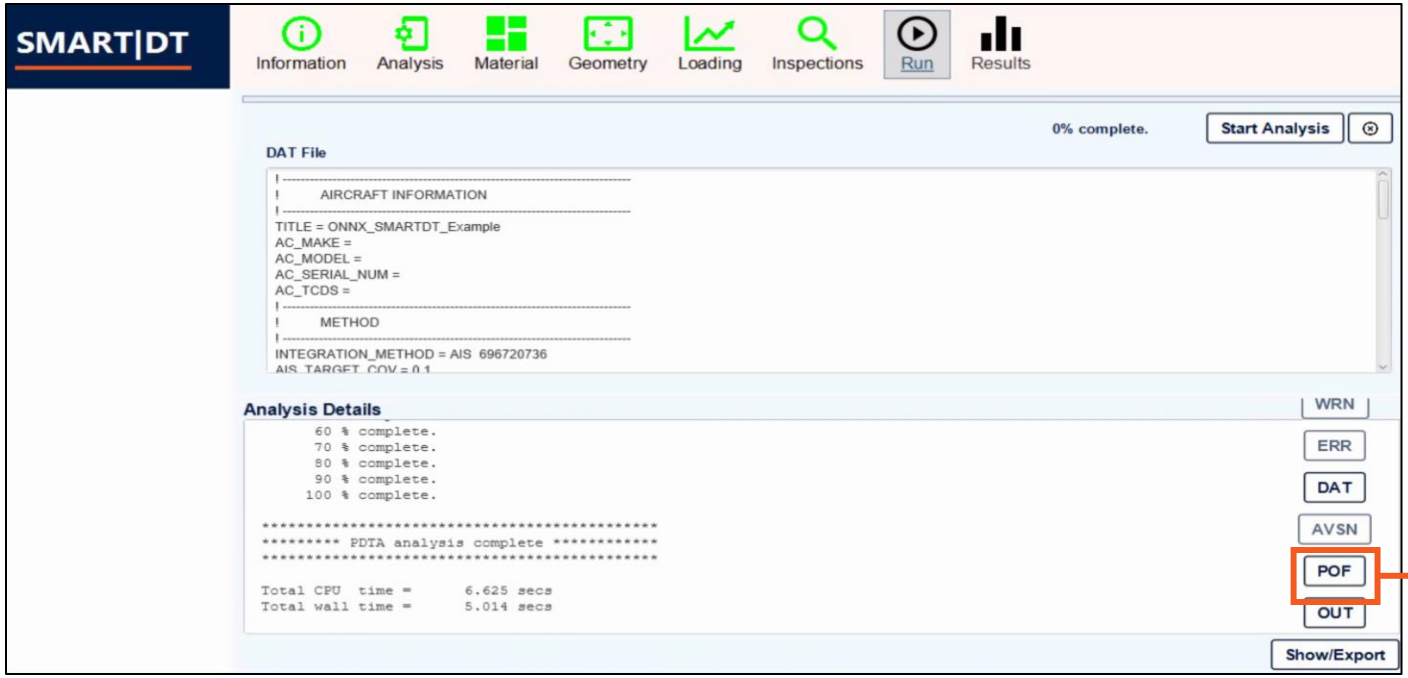
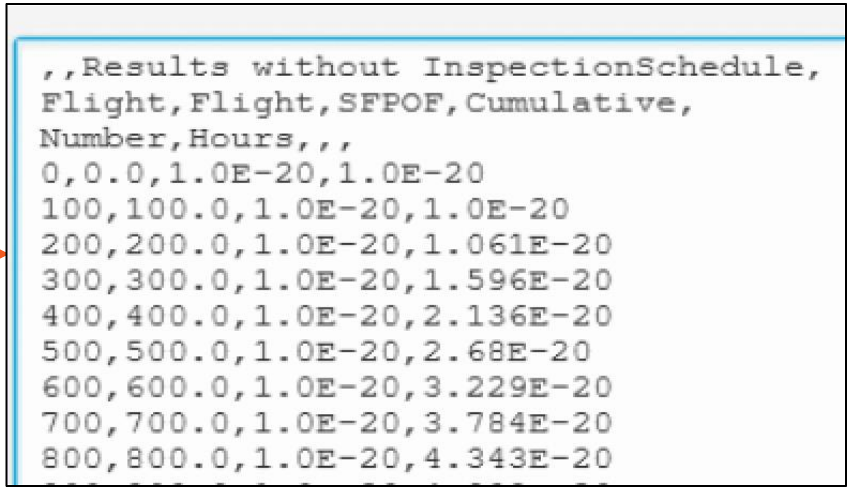
Step 9: Run Pane (cont.)

ONNX Example

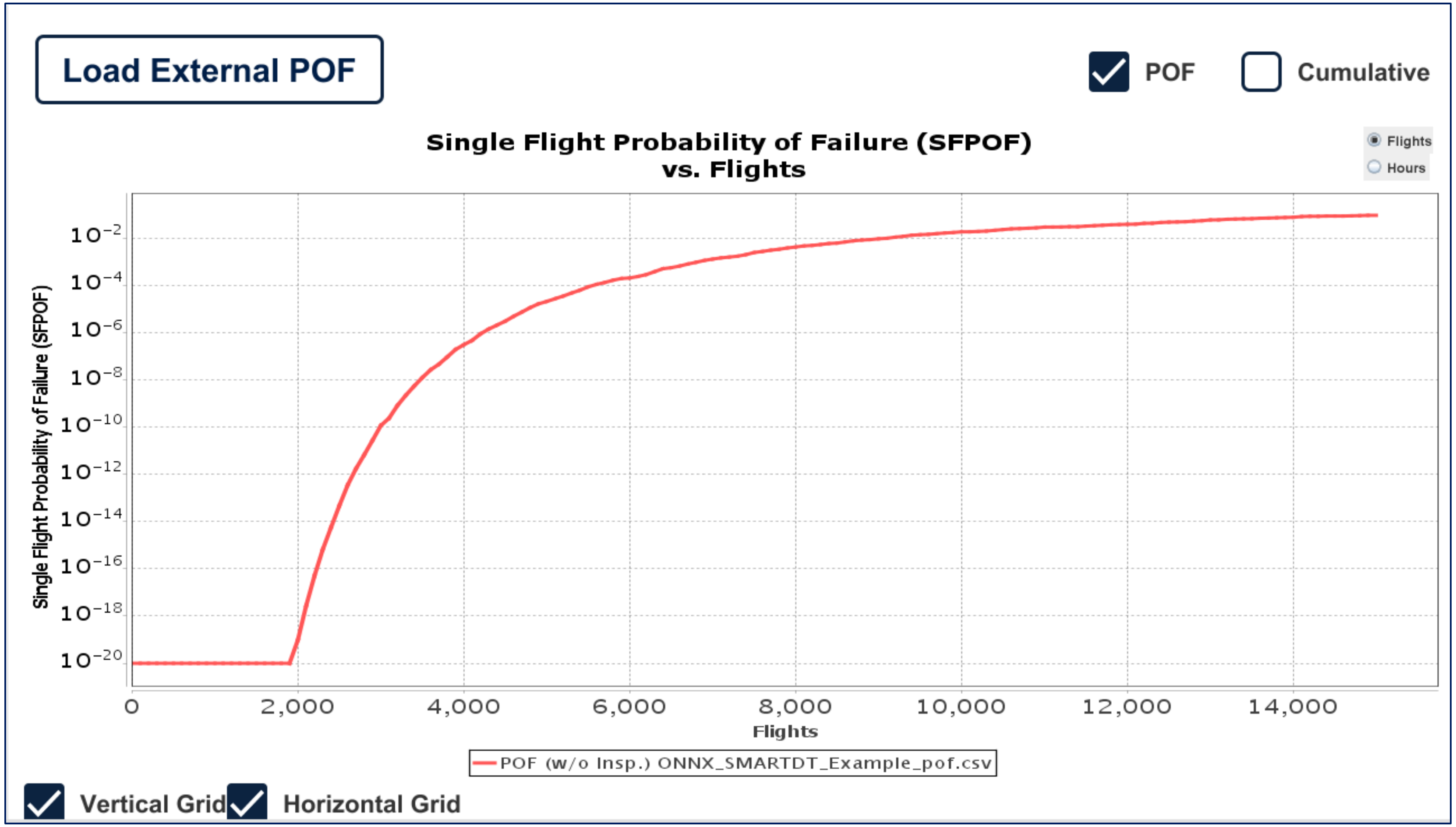




- Click the **POF** button to view the SFPOF and Cumulative SFPOF at each flight.

Step 10: Results Pane

ONNX Example



- Visualize the SFPOF in the **Results** window.
- Click Hours or Flights to visualize the SFPOF in either unit.

Compare Your Results

ONNX Example

- Compare your SFPOF values against those in the file **ONNX_SMARTDT_Example_pof.csv**.
- Load the file **ONNX_SMARTDT_Example.smdt** into the GUI and compare your SFPOF plot.